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Contributions from the
Virginia Museum of Natural History

Number 19 | 10 January 2009

Unusual Cambrian Thrombolites from the Boxley Blue Ridge Quarry, Bedford County, Virginia

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ISSN 1061-1878

Virginia Museum of Natural History
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Jeffersoniana, Number 19, pp. 1-14
Virginia Museum of Natural History

Unusual Cambrian Thrombolites from the Boxley Blue Ridge Quarry, Bedford County, Virginia

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ABSTRACT

Three unusual thrombolites were collected in June 2008 from the Late Cambrian Conococheague Formation at the Boxley Materials Blue Ridge Quarry in Bedford County, Virginia. These specimens are isolated low domes with a thrombolitic core and a pustulate, stromatolitic outer layer. The two largest domes have a distinctive thickened rim around their margins. There are apparent traces across the upper surfaces of the domes that may indicate grazing by invertebrates.

The overall structure and morphology of the Boxley specimens is reminiscent of modern thrombolites forming in Lake Thetis, a saline lake in southwestern Australia. The low domes and thickened rims in Lake Thetis specimens seem to be a result of growth in a protected setting, with shallowing water levels. Based on the similarities with the Lake Thetis specimens, the Boxley thrombolites may have formed in a protected lagoonal setting with gradually dropping water levels, followed by relatively rapid inundation and burial.

INTRODUCTION

Stromatolites are a common occurrence globally in Proterozoic and Cambrian sediments, and occur less frequently in post-Cambrian deposits up to the present day. Examination of modern forms has demonstrated that stromatolitic and thrombolitic mounds are constructed primarily by a variety of blue-green algal communities (Black, 1933; Logan, 1961; Sharp, 1969; Reid et al., 2000), although laminated structures reminiscent of algal stromatolites can be formed by other organisms or by abiotic processes (Logan et al., 1964; Ahr, 1971; Walter, 1976; Grotzinger and Rothman, 1996). Stromatolitic structures can assume a variety of morphologies

that are influenced both by the taxa present and environmental conditions (Black, 1933; Logan et al., 1961; Dill et al., 1986), and most of these have been observed in both modern and ancient stromatolites (Logan, 1961; Hoffman, 1976).

Modern stromatolites are largely restricted to hypersaline environments, with a few exceptions (Dill, 1986). The extensive geographic range of stromatolites in the Proterozoic and Cambrian suggests that stromatolites previously lived in a greater variety of habitats than do modern examples, and that the presence of stromatolites is not necessarily an indicator of an intertidal setting (Aitke, 1967; Playford and Cockbain, 1969). The decline of stromatolites beginning in the late Cambrian has lead to suggestions that the rise of grazing and burrowing metazoans in the Cambrian resulted in the restriction of stromatolites to marginal environments after that time (Awramik, 1971; Walter and Heys, 1985), although open-marine stromatolites have been found in Devonian deposits (Playford and Cockbain, 1969). The presence of burrowing metazoans may have also led to the appearance of thrombolites (unlaminated algal mounds) in the Cambrian (Walter and Heys, 1985).

GEOLOGIC SETTING

The Late Cambrian Conococheague Formation in Virginia and Maryland is a thrombolite- and stromatolite-rich limestone that has been interpreted as a shallow subtidal to peritidal deposit (Demicco, 1983; Osleger and Read, 1991). Regressive cycles up to 10 m thick tend to have basal thrombolitic beds overlain by cross-stratified oolitic grainstones grading into bioturbated and mud-cracked rhythmites (“ribbon rock” of Demicco, 1983). The cycles are capped by laminated and stromatolitic limestones and dolostones. A section of the Conococheague is exposed in the Boxley Materials Blue Ridge Quarry in Bedford County, Virginia (Demicco, 1982). This quarry is located within the Blue Ridge fault zone, and a highly deformed allochthonous block of the Conococheague Formation, overlain by the overthrust Elbrook Formation, has been exposed during quarrying operations over the last century (Figure 1). The lithologies and cycles present in the Blue Ridge Quarry are comparable to other Conococheague localities in Virginia and Maryland.

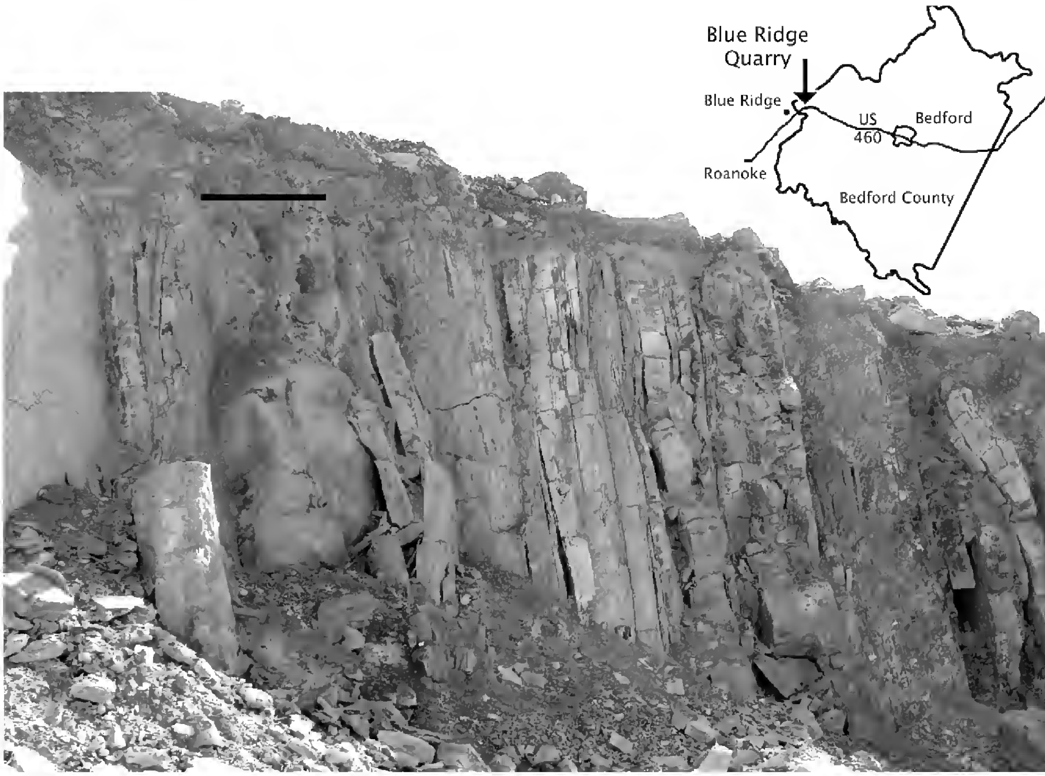

Figure 1. Section of the Conococheague Formation at the Blue Ridge Quarry. The black line is approximately 2 meters, and indicates one of the thrombolitic beds. Inset: map of Bedford County, Virginia showing the location of the Blue Ridge Quarry.

DESCRIPTION

In June 2008, Boxley employee Richard Benge discovered a large, isolated thrombolite in blast-produced tailings during operations at the Blue Ridge Quarry (VMNH 160000; Figure 2). After discovery of this specimen, additional examination of tailings from that blast revealed two additional, much smaller bioherms (VMNH 160001; Figure 3). The largest of these specimens is a low dome, subcircular in plan view with a long axis diameter of 190 cm and a short axis diameter of 180 cm. While much larger bioherms have been described (see for example Ahr, 1971), the Boxley specimen represents one of the larger complete and intact specimens collected, and is unusual among Conococheague thrombolites in that it represents a complete bioherm.

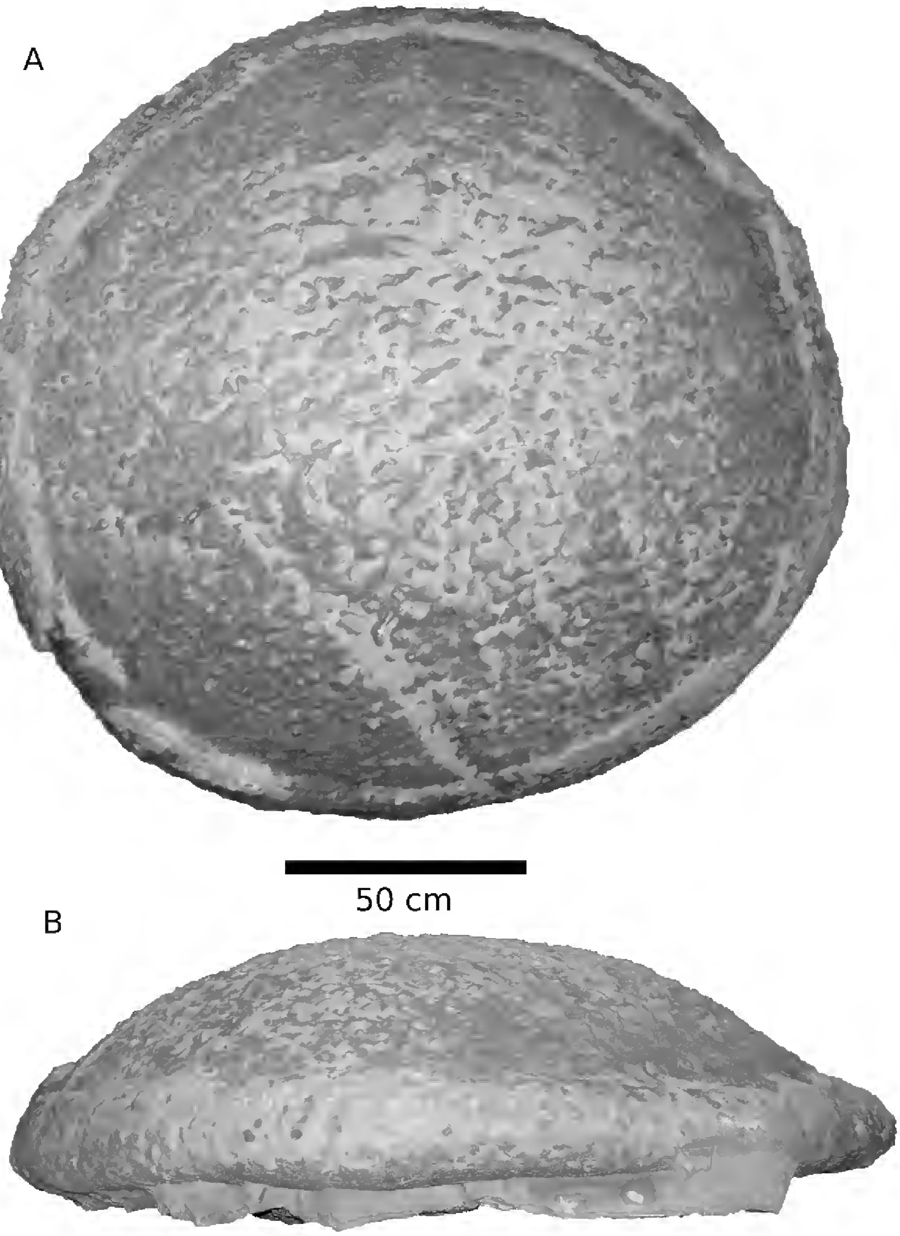

Figure 2. VMNH 160000 thrombolitic bioherm. A, surface view. B, profile view. Scale = 50 cm.

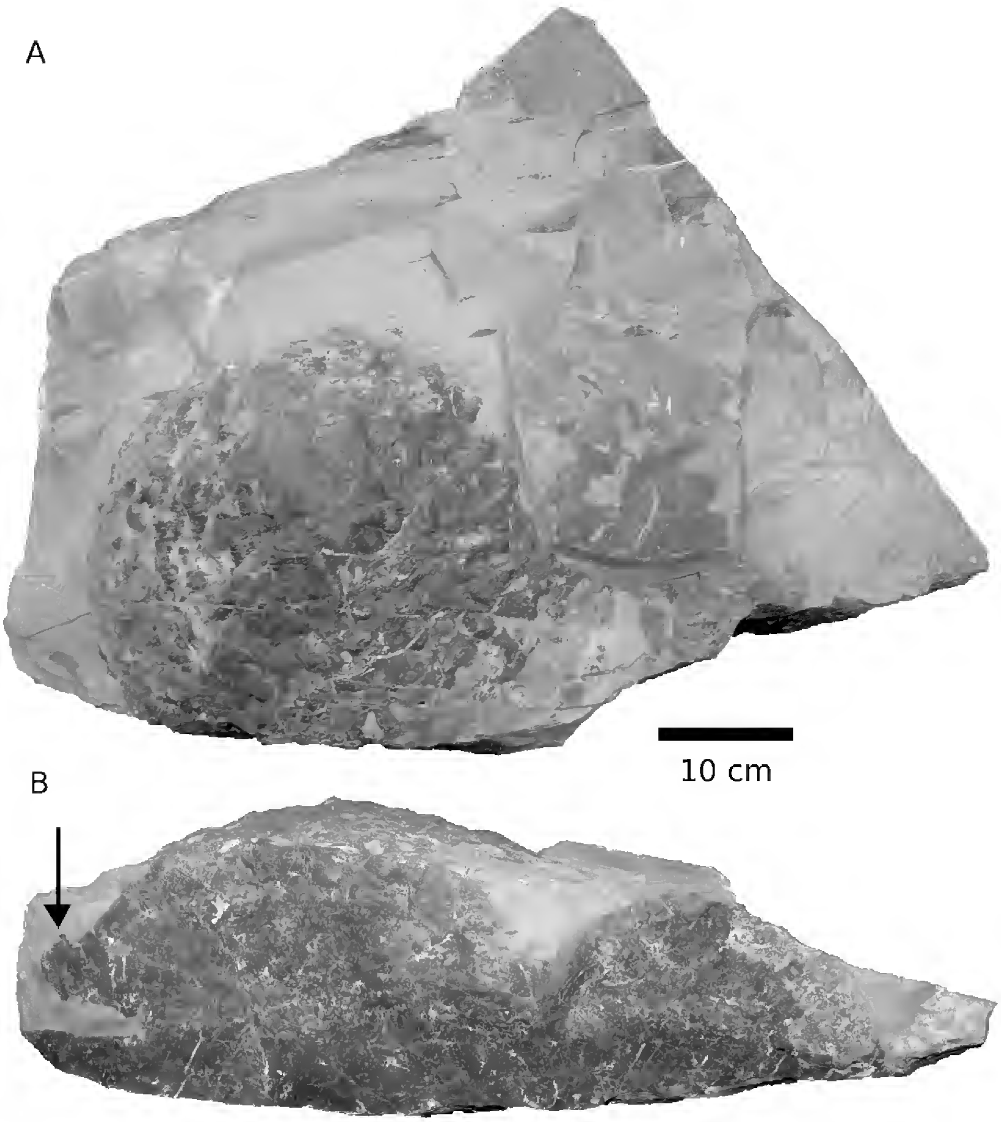

Figure 3. VMNH 160001 thrombolitic bioherms. A, surface view. B, cross-section. Arrow indicates thickened rim. Scale = 10 cm.

The internal wackestone - to - mudstone fabric with *Renalcis* algal structures of the Conococheague thrombolites was described in detail by Demicco (1982). Internally, all the Boxley specimens have a mottled appearance; throughout most of the structure laminations are sparse, discontinuous, and located only near the tops of the domes. The outer ~5 mm of the domes are stromatolitic, with distinct knobs covering the upper surface of the dome (Figure 4). These knobs are generally circular to oval in outline, and are up to approximately 3 cm in diameter.

Renalcis are not obvious in these thrombolites, but filaments that could represent algal structures are visible in places in the stromatolitic layer (Figure 5).

While the internal structure of the Boxley specimens is similar to that of typical Conococheague stromatolites/thrombolites, the overall morphology is quite different. Most Conococheague bioherms are widening-upward structures, which are flat-topped and merged together at their tops, often reaching thicknesses of many meters (Demicco, 1982; Osleger and Read, 1991; Figure 1). The thrombolitic units are very noticeable in most of the deposits in the Blue Ridge Quarry. In contrast, VMNH 160000 and 160001 are low-profile domes that narrow upward. The two small domes are coalesced only at their bases, while the largest specimen is isolated.

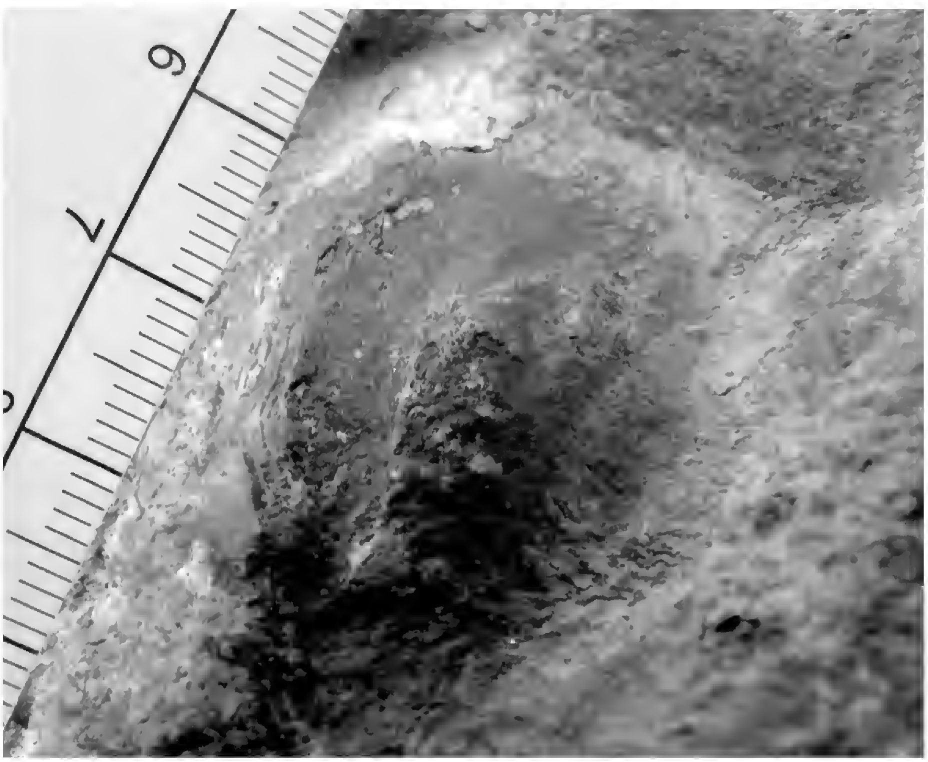

Figure 4. Knob on the surface of VMNH 160000, showing stromatolitic layers.

A unique feature of the Boxley thrombolites is the presence of a thickened rim around the margin of the mounds. This rim completely encircles the mound in VMNH 160000 and at least partially surrounds

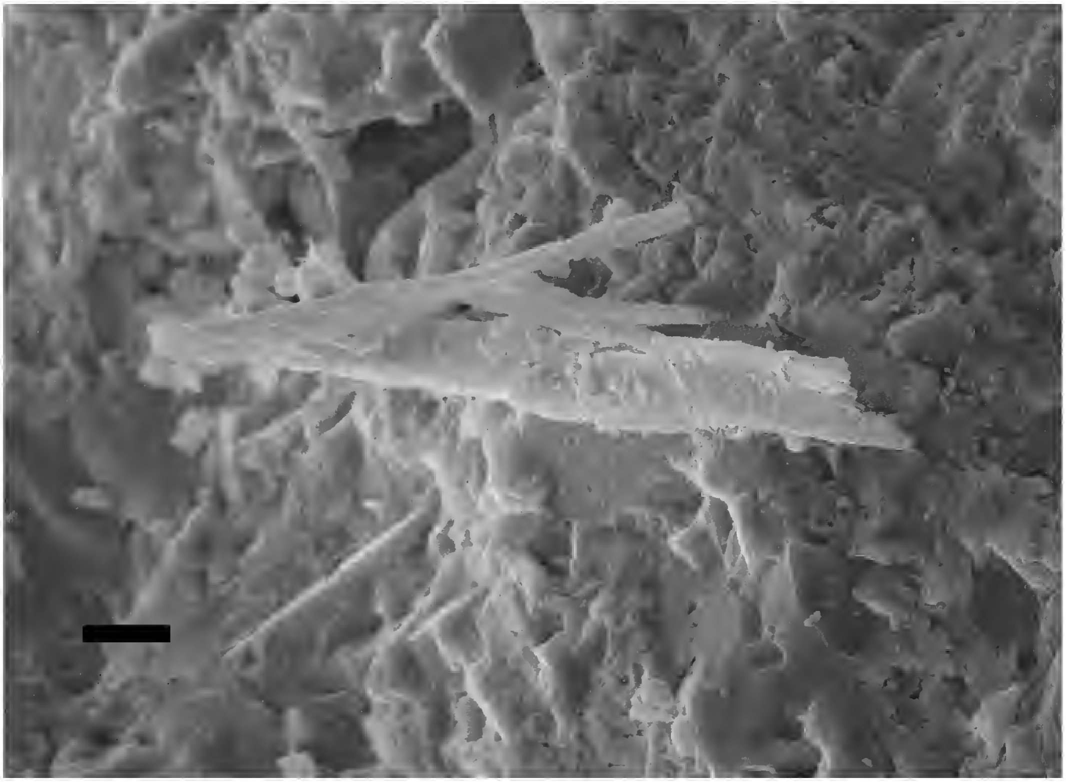

Figure 5. Scanning electron micrograph of a section of the stromatolitic layers of VMNH 160000, showing a possible algal filament. Scale = 10 μm.

the larger mound in VMNH 160001 (Figures 2 and 3); the smallest dome seems to lack this rim. In VMNH 160000, the thickened rim is thrombolitic with a pustulate, stromatolitic outer layer, just as in the main part of the dome.

The upper surfaces of the thrombolites exhibit a small number of apparent traces, in the form of meandering grooves (Figure 6). These grooves are approximately 3 mm wide and cut across both the stromatolitic knobs and the troughs between adjacent knobs. As each trace is restricted to the stromatolitic layers (the living part of the dome), and runs tangential to the surface of the thrombolite, they are more consistent with feeding traces than residence burrows. The large, primitive chiton *Matthevia* has been interpreted as a grazer of stromatolites and is known from the Conococheague Formation (Runnegar et al., 1975), although it has not been identified at the Blue Ridge Quarry. *Matthevia* would be expected to leave a feeding trace approximately 3 mm wide, assuming that the relative proportions of its mouth and valves were comparable to those of modern chitons.

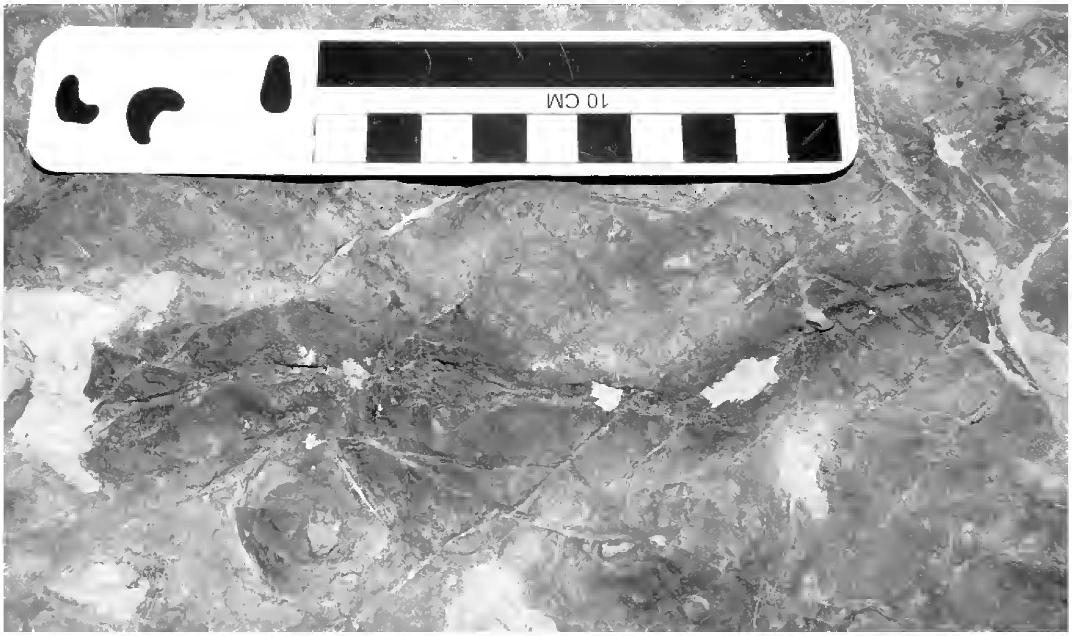

Figure 6. Possible feeding trace on the surface of VMNH 160000.

DISCUSSION

In general, the Conococheague thrombolite units have been interpreted as forming in the shallow subtidal zone (Demicco, 1982, 1983), consistent with general suggestions about thrombolite distributions suggested by Aitken (1967). These thrombolitic beds are often several meters thick, with the individual thrombolitic heads coalescing into a contiguous mass at the top of the unit. This pattern is typical throughout the Conococheague, including at the Blue Ridge Quarry. However, VMNH 160000 and 160001 differ from this pattern, in that the heads are low in profile and isolated, and have unusual thickened rims. In the section of the quarry where these specimens were collected there is no obvious thrombolitic unit, and no comparable isolated thrombolites were found in place. This suggests a somewhat different history for the Boxley specimens, compared to typical Conococheague thrombolites.

The overall morphology of the Boxley thrombolites is reminiscent of modern stromatolites/thrombolites forming in Lake Thetis, a saline coastal lake in Australia (Grey et al., 1990). The morphology of the Lake Thetis thrombolites appears to be a result of unique conditions found in that environment.

Lake Thetis is a small saline lake fed by rainfall and groundwater input, with a maximum depth of about 2.25 m (Grey et al., 1990). There is a complex and diverse array of algal structures present in and around the lake, including lithified stromatolites along the southwest shore that were described in detail by Grey et al. (1990). These stromatolites are low steep-sided domes comparable in size to VMNH 160000, with diameters up to around 1.5 meters, and extend well above the lake surface (Figure 7). The centers of these domes are eroded and often collapsed, with active growth only occurring along the wetted sides of the domes. The inside of the domes are thrombolitic, with a stromatolitic outer layer. The stromatolitic layer is composed of laminated columns about 1.5 cm in diameter and approximately 5 to 15 cm thick, which give the outer surface of the dome a pustulate appearance. This is very similar to the structure of the Boxley thrombolites, although in the Boxley specimens the outer stromatolitic layer is only a few millimeters thick. The Lake Thetis domes, and particularly the stromatolitic layers, are limited to the south shore of

Figure 7. Thrombolitic domes from Lake Thetis, southwestern Australia. Individual domes are approximately 1 meter in diameter. Image by Ruth Ellison, retrieved on 18 November 2008 from http://flickr.com/photos/laruth/153584043/. Used with permission.

the lake where wave activity is low, possibly because a gelatinous coating does not develop under high-energy conditions (Grey et al., 1990).

Some of the Lake Thetis thrombolites have a thickened rim reminiscent of the Boxley specimens (Figure 7). In modern structures this rim seems to have formed as a result of the drop in water level in Lake Thetis over the last several thousand years (Grey et al., 1990; Figure 8). The exposed stromatolitic domes erode and collapse when desiccated, even as growth continues along the wetted margins of the dome. This suggests that a drop in relative water level exposing the center of the dome is necessary for the formation of the thickened rim.

Figure 8. Google Earth image of Lake Thetis. Black arrows indicate past shorelines of receding lake. White arrow indicates the position of modern thrombolitic domes. Image retrieved on 18 November 2008.

The Boxley thrombolites differ from the Lake Thetis examples in that the thickened rim is combined with a large, well-developed thrombolitic

dome, suggesting a more complex history of water level variation than the steady drop observed in Lake Thetis. The unique morphology can be explained by a scenario in which stromatolite growth was initiated in a protected setting, such as a back-barrier lagoon. The shallow, low-energy water would prevent the development of large bioherms while allowing the growth of broad, low domes, with simultaneous deposition of carbonate muds. A slight drop in water level restricted growth to the margins of the dome, resulting in the development of the thickened rim. A subsequent increase in water level (perhaps due to a breach of the isolating barrier) buried the largest thrombolites under coarser-grained carbonates. Efforts to locate isolated domes in situ have so far been unsuccessful, even though their approximate position is known. That this section of the quarry also seems to lack the basal thrombolitic beds typically found in Conococheague cycles suggests that this limited area experienced somewhat different conditions from the rest of the formation.

ACKNOWLEDGMENTS

I would like to thank Boxley Materials Company, and particularly Ab Boxley, Bill Hamlin and Tom Roller, for their donation of these specimens to the Virginia Museum of Natural History and their continued access to the Blue Ridge Quarry. Ruth Ellison provided images of the Lake Thetis stromatolites. I would also like to thank James Beard, Brett Dooley, and Andrew Moore for helpful discussions, Mary Catherine Santoro for assistance in obtaining references, Mary Carmen for SEM images, and the Jeffersoniana editorial board and outside reviewers for helpful comments.

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